FRESHWATER TURTLE POPULATIONS IN THE AREA TO BE FLOODED BY THE WALLA WEIR, BURNETT RIVER, QUEENSLAND: BASELINE STUDY

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A baseline turtle study was requested in a review of impacts of changed water levels to follow construction of the Walla Weir on the Burnett River (25°02'S, 152°04'E) at Wallaville, Queensland. Four species of freshwater turtle occur in the area. *Emydura krefftii* was abundant throughout most of the Walla Weir area. This population's characteristics indicate poor recruitment or survivorship of young turtles, even though adults breed at a very high rate; a size class distribution skewed towards adults; a sex ratio of 1:1; and almost all adults breeding annually. The straight carapace length (SCL) at which 50% of the population had matured to adult status was used to define size at first breeding and was 18.9cm for males and 21.1cm for females. Mean of all adults was SCL = 22.9cm for males and 25.1cm for females. Length/weight analyses measure health and body condition for each sex. *Elseya* sp. was uncommon in the area and was mostly concentrated in a single pool. *Elseya* sp. has a well-developed cloacal gill system. Its population structure indicated that the population was not performing well. Captured turtles comprised large adults and a group of immature turtles born in about 1990-1991. Recruitment of young appears to be limited. *Chelodina expansa* and *Elseya latisternum* occurred at very low density in the study area. A set of parameters to describe population performance of chelid turtles and suitable for short-term studies is identified: size class distribution by sex and maturity; and size at first breeding, mean size of adults, annual breeding rate, and length/weight condition curves for each sex. ❐ *Freshwater turtle, population, Walla Weir, Burnett River, Queensland.*

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As a result of opinions expressed during the environmental impact assessment of the proposed Walla Weir on the Burnett River (25°02'S, 152°04'E), the Commonwealth Minister for the Environment commissioned a review of information relating to the impact of such weir on the lungfish, *Neoceratodus forsteri*, and the undescribed freshwater turtle, *Elseya* sp. This review (Boardman, 1996) concluded that the weir was unlikely to impact significantly on the lungfish and that only a small part of the total distribution of the turtle would be affected. However, this same review identified the cumulative impacts of present and future dams and weirs in the Burnett R. as a more significant issue, and recommended that a long-term program be established to collect baseline data on the lungfish and *Elseya* in the Burnett, Mary and Fitzroy River systems. The present study was undertaken in response to this and was part of a larger study to investigate the impact of dams and weirs on freshwater turtles in the Fitzroy, Burnett and Mary River catchments.

The Australian freshwater turtle fauna is dominated by Chelidae and species taxonomy is still being resolved (Georges, 1994; Manning & Kofron, 1996; Cann, 1998). Chelid turtles are long-lived (Kennett, 1994; Parmenter, 1985) and there are few long-term studies of Australian freshwater turtles, except for *Pseudemydura umbrina* (Kuchling & Bradshaw 1993; Kuchling et al., 1992), that can address the dynamics of populations in response to threatening processes. Gathering comprehensive demographic data for turtles can be expected to take decades (Gibbons, 1989; Congdon et al., 1993), although the process could be quicker with rapidly maturing species such as *Chelodina rugosa* (Kennett, 1994). By contrast, and in the context of planning for the increasing demand for water for agricultural and pastoral use in south and central Queensland, answers to questions concerning the impact of dams and weirs on turtle populations are required in the immediate future. Resolving these conflicting time scales lies at the crux of the problem when attempting to provide freshwater turtle baseline data as recommended by Boardman (1996).

With the limited time available before the anticipated elevation of water levels in the Walla

Weir in late 1997, it was impracticable to plan for long term ecological studies for the site. In addition, extended rains with elevated water flow in the Burnett R. hindered turtle capture during November 1996 - April 1997 and curtailed study during the one breeding season available within this baseline study period.

A description of population dynamics with respect to age structure, size distribution, sex ratio, maturity ratio, annual breeding rates, fecundity and survivorship provides more information on how a population is performing than studies that focus on census and distribution. A rapid assessment method targetting key parameters was needed for the baseline study of *Elseya* sp. before water levels rose. Not all population dynamics parameters would be equally useful. For example, no validated method for age determination of Australian freshwater turtles existed, while survivorship measurements would require some years of mark-recapture studies. In-depth studies of a population through several breeding seasons would be needed to quantify inter-annual variability of fecundity with respect to eggs per clutch, clutches per season and incubation success of clutches. However, short term sampling of turtles in an area should be able to describe a population with respect to size, sex, maturity and breeding status of the individuals. From these data it is possible to quantify a range of population parameters including sex ratio, size class distribution by sex, size at which each sex reaches adulthood, mean size of breeding adults and annual breeding rate of adults of each sex. These are demographic parameters that can be measured within a single year and have the potential to change in response to long term changes in living conditions and health of the turtles. When compared across time, they should detect changes in population function. For example, Kuchling & Bradshaw (1993) recorded that ovulation and egg production of captive *P. umbrina* was easily suppressed under stress or sub-optimal conditions. While not immediately informative, other than to ensure that the same animal was not counted twice, establishment of tagged populations facilitates investigation of other demographic parameters such as growth, dispersal, migration and survivorship across the years after the rise in water level.

However, results from short term studies must be used cautiously. There are few databases for chelid turtles against which to judge how such parameters may vary in response to changing climate, independent of any changes due to dam or weir construction (Kennett & Georges, 1990). Turtle population structure is not completely dependent on in-river processes (Thomson, 1983). Anthropogenic terrestrial influences (independent of the aquatic environment) may have significant impact on turtle population dynamics during the terrestrial phase of egg incubation. For example, predation of eggs and hatchlings by foxes or pigs, trampling of nesting banks by stock or overgrowth of nesting banks by weeds could reduce hatchling recruitment. Therefore, it is highly unlikely that there is a short term solution to understanding the impact of dams and weirs on conservation of freshwater turtles.

This baseline study was to examine freshwater turtles in the proposed Walla Weir area of the Burnett R. prior to the rise in water level. The turtles were investigated from the perspective of population function using analyses addressing sex, maturity and breeding status of measured individuals from within a tagged population. While maintaining a general approach to address all species present, special emphasis was placed on *Elseya* sp.

METHODS

Specific nomenclature follows Georges & Adams (1992), Georges (1994) and Cann (1998). *Elseya* sp. in the Burnett R. is treated as an undescribed species resembling *Elseya dentata* from the Northern Territory (*Elseya* sp. aff. dentata [Burnett]. Georges & Adams, 1996). This species in the Burnett and adjacent rivers is being described as new (S. Thomson, personal communication.). A voucher specimen of the species has been registered in the Queensland Museum: J67876. Although *Emydura krefftii* may be synonymous with the widely dispersed polytypic *E. macquarii* (Georges & Adams, 1992,1996; Georges, 1994), formal taxonomic revision accounting for these genetic studies has yet to be completed. Until it is we use *Emydura krefftii* for the Burnett R. population.

Where water clarity permitted, turtles were hand captured while snorkelling by day or using spotlighting at night. In turbid water, turtles were captured using seine nets, dip nets or funnel traps. The seine nets (30m length, 3m fall, 15cm mesh size) were dragged through large pools and, because of the mesh size, captured only large immature turtles and adults. These nets were inefficient in those sections of the river with depths exceeding the fall of the net. Dip nets were scooped through shallow areas of dense aquatic vegetation in search of small turtles. A range of size and design of funnel traps were used and were baited with bread or punctured cans of sardines in vegetable oil. Traps were set completely submerged and checked at 1-2hr intervals or were set partly submerged to permit trapped turtles or platypus to breathe and checked at 2-4hr intervals. Following their capture, turtles were held in bags or plastic bins in the shade for up to 24hr and processed for tagging, measurements, and gonad examination. Turtles were released at their respective capture sites.

Linear measurement of turtles were made with vernier slide callipers (±0.01cm) or, for large turtles, with wooden callipers and a steel rule (±0.1cm). Straight carapace length (SCL) was measured from the anterior midline margin of the carapace to the posterior midline margin of the carapace. Straight carapace width (SCW) was measured at the widest part of the carapace perpendicular to the midline axis of the carapace. Plastron length (PL) was measured from the middle anterior to the middle posterior of the plastron. Plastron width (PW) was measured perpendicular to the midline axis of the plastron immediately anterior to the bridges. Head length (HL) was measured from the anterior tip of the maxillary sheath of the jaw to the posterior tip of the supra-occipital process. Head width (HW) was measured across the widest part of the head behind the ears at the quadrate bones. Tail measurements were taken from the tip of the firmly out-stretched tail to the plastron (TLP), to the anterior of the vent (TLV) and to the posterior mid-point of the carapace (TLC). Turtles were weighed with either a 10kg or 15kg hanging spring balance (±0.1kg) or with a 2kg top-pan electric balance (±1gm). Plastron curvature was scored as concave, convex or flat by inspection with a straight edge laid over each of the length and width of the mid plastron.

Each turtle was individually identified with one or both of the standard freshwater turtle tagging systems used in the Queensland Turtle Research Project. Numbered self piercing, self locking, monel tags originally designed as chicken wing bands (National Band and Tag Company, Newport, Kentucky, USA) were applied through the webbing between digits 4 & 5 of a rear foot of the turtle. For small turtles with SCL<15cm, the tag was not applied through the webbing of the hind foot but was applied through marginal scute 11 counting from the anterior. Most turtles received a coded carapace notching: marginal scutes of the carapace are assigned a letter code in order from the right front in a clockwise direction; one or more notches are cut into the marginal scutes each to a depth of approximately one third of the width of the scute to provide a series of coded turtles a,b,c, ...z,ab,ac,ad,......az,bc,bd, ..., abc,..... ; the nuchal was not used for notching; no more than one notch was applied per marginal scute.

Gonads and associated reproductive ducts of live turtles were examined visually to determine sex, maturity and current breeding status using laparoscopy with a Carl Stortz 26031B or 28300B Hopkins telescope, depending on the size of the turtle, connected to a Carl Storz 482B cold light source and inserted through a 7mm or 3mm o.d. cannula, respectively. Access to the abdominal cavity was achieved via a small scalpel cut in the skin adjacent to the anterior ventral margin of the right inguinal area. The cut was limited to ensure a firm fit of the cannula. Throughout the examination the turtle was firmly hand held vertically with its head downwards. The turtle's right leg was manually distended posteriorly to minimise disturbance of the instruments. On completion of the examination, the cut to the skin was closed with an absorbable suture (catgut chromic #3). Instruments were stored in and used from a 70% ethanol bath. The inguinal area was scrubbed with 70% ethanol prior to making the incision. To facilitate viewing of the organs, the abdominal cavity was inflated with air, as required, from a hand-operated pump. This methodology follows closely that developed for similar studies with crocodiles and marine turtles (Limpus, 1984, 1992; Limpus & Reed, 1985; Limpus et al., 1994a,b). Sex was determined by the presence of either an ovary or testis. Immature females were recognised by their straight or partly enlarged (partly convoluted) oviducts that were circular to oval in cross-section and an unexpanded ovary. Adult females were characterised by the presence of one or more of the following: enlarging vitellogenic follicles; mature follicles; corpora lutea, corpora albicantia or large atretic follicles in an expanded ovary. Oviducal egg may be present in the adult female. A flattened and greatly convoluted oviduct was a feature of all adult females identified by the above criteria and was used in assigning adult status to turtles that have completed enlargement of the ovary but displayed no signs of present or past breeding activity. Immature males had the epididymus still within the body wall or incompletely enlarged from the body wall while adults had an epididymus that was enlarged and pendulous from the body wall. The presence of oviducal eggs identified by palpation was used to identify adult females among turtles whose gonads were not viewed. Large short-tailed turtles selected for palpation were held vertically with the head upwards while shaking them gently and at the same time squeezing fingers firmly into the inguinal areas to feel for oviducal eggs.

Using dose-effect terminology, the size at which 50% of the turtles are sexually mature can be termed 'adult size$_{50}$' (AS_{50}). The proportion of adult turtles in 1cm size increments for each sex was analysed using simple logistic and gompertz functions to estimate the AS_{50} values. Goodness of fit was based on residual variance and log likelihood functions.

Eggs laid onto the container floor while a turtle was being held for measurements were placed with minimum rotation in a covered plastic container of sand from a freshwater stream moistened to 6% by weight with freshwater. The container was covered with a thin polythene sheet to minimise water loss and placed in a well ventilated room out of direct sunlight to incubate at "room" temperature. Incubation temperatures were not measured. Eggs and hatchlings were measured with vernier calipers (±0.01cm) and weighed on an electric top-pan balance (±0.1g).

Nomenclature of scutes follows Pritchard & Trebbau (1984) except that 'supracaudal' scutes are included in the marginal scute count. Age estimate for small turtles that retained a complete set of growth layers on their scutes, presumed that growth layers are deposited annually.

STUDY AREA

The study area is the main stream of the Burnett R. that will be flooded following construction of the Walla Weir 74.5km upstream from the mouth and approximately 19km downstream from the existing (1997) Bruce Highway traffic bridge at Wallaville. We examined 19 sites (Table 1) over 25km of river extending from 6km upstream of the Bruce Highway bridge downstream to the Walla Weir. These sites are referred to as the Walla Weir area of the Burnett R. The study sites were of irregular length and identified by prominent land marks or natural changes in the stream such as narrow shallow areas between larger pools. Latitudes and longitudes were recorded using a Geographical Positioning System (GPS) recorder.

The dry season stream was continuous, usually 10-20m wide and flowed slowly in a much wider dry sandy to gravel river bed. The dry season stream, usually <3m deep, varied from a few cm to ~6m deep. During floods the stream may be tens of metres deep. The river substrate was compacted sand with few rock outcrops. Only in some of the larger, wider and deeper pools was there a substantial silt substrate. As the stream meandered within the dry season river bed, one bank was usually flanked with a narrow fringe of riparian vegetation, predominantly *Melaleuca*, *Callistemon* and *Casuarina* mixed with a wide range of rainforest species, overhanging the water. Breaks in this narrow fringe of trees were frequently dense with weeds. The opposite bank was usually a shallow sand flat with little vegetation other than young regrowth *Melaleuca* and *Callistemon*, sedges and grasses. This latter bank was heavily trampled and grazed by cattle. Where there were large overhanging trees at the stream margin, there were usually deeply recessed cavities under the bank that were supported by the root mass of the trees. Also where there were large trees on the river bank there were often numerous submerged snags, mainly tree trunks, branches and roots. Fence posts, barbed wire and other agricultural debris frequently were entangled in these snags.

There was considerable variability in the macrophyte community in the river. During December 1994 - January 1995 much of the stream bed was densely overgrown with aquatic macrophytes and in some sites the submerged macrophytes exceeded 2m in height. The high rainfall during the 1995 wet season and subsequent increased river flow removed almost all of these dense macrophyte stands. Substantial regrowth was not in evidence until mid 1997.

Study sites 8-12 were sampled prior to the Boardman (1996) review and a team of snorkellers swam the length of this section once and sites 10-12 an additional five times during December 1994-January 1996. For 10 of the sites (number 8-17) that were continuous over approximately 6km of river, a team of snorkellers swam the length of the section on three separate occasions during July-August 1997. Turtle captures were supplemented by trapping in sites 13-19 during this same period. During the turbid water period in October 1996 - February 1997, sites 1-12 were sampled only by seine-netting, dip-netting and trapping. One site (number 11) was sampled on all sampling trips and using all sampling techniques at various times.

TABLE 1. Study sites sampled during the baseline study of freshwater turtles within the Walla Weir area of the Burnett River. Sites are numbered sequentially from upstream to downstream.

Site number	Latitude & longitude	Maximum depth (m)	Description
1	25°07.99'S, 151°58.99'E	1.5	Impoundment area of a small flow rate weir ~1.5km upstream of proposed bridge site (site 3).
2	25°07.93'S, 151°58.95'E	2	Backwater to main stream, downstream of site 1.
3	-	1	Shallow rocky area 600m upstream from site 4. Rainforest riparian margin on northern bank.
4	-	2	New Bruce highway traffic bridge which replaced the highway bridge which was in use at the time of the study. Firm compacted sand with few rocks or snags.
5	25°07.19'S, 151°59.20'E	2	Main stream 100m downstream of site 4.
6	-	2	Pool at end of small rapids 300m downstream from site 5.
7	-	2	End of the backwater (200m downstream from site 6).
8	-	2	Extends upstream from old traffic bridge for ~750m. Firm sand bottom with few rocks. Narrow stream along northern bank with overhanging trees.
-	25°05.7'S, 151°59.71'E	-	Old Bruce Highway traffic bridge at time of study.
9	-	2	Extends downstream from old traffic bridge for ~300m. Narrow stream on northern bank with overhanging trees.
10	25°04.76'S, 151°59.86'E	2	Narrow stream along northern bank with overhanging trees. Larger pools associated with large fallen trees.
11	25°04.69'S, 151°59.90'E	6	Deep pool on bend of river with structural remains of the water intake system for the old Wallaville Sugar Mill. Within this pool, rock crevices replace the refugia provided by overhanging root masses, fallen logs and snags that occurred in pools upstream. Includes backwater of creek entering from the northern bank.
12	25°04.69'S, 152°00.00'E	1	Continuing downstream from site 11 to the next shallow rapids. (100m downstream of site 11)
13	25°04.31'S, 152°00.15'E	5	Steep sided pool beginning in gravel rapids and terminating in rock outcrop with riffle area. Course gravel and submerged rocks and logs mid stream.
14	25°04.42'S, 152°00.29'E	2.5	Starts and finishes at prominent rock outcrops into the stream. Rocky bottom in parts and submerged boulders and logs midstream.
15	25°04.44'S, 152°00.39'E	1.5	Narrow stream along northern bank with overhanging trees; mostly shallow sand bottom with interspersed small pools. Terminates where stream opens out into broad pool of site 16.
16	25°04.56'S, 152°00.56'E	1.5	Broad and mostly shallow, extensive Vallisneria beds; few logs.
-	-	-	Murray's Crossing.
17	25°05.04'S, 152°01.16'E	2	Sandy to course gravel bottom.
18			This section not examined in detail.
19	25°05.26'S, 152°02.15'E	2	Long pool on southern side of "island" adjacent to the end of Pine Grove Park Road. Mud bottom with occasional sand and gravel areas. Terminates on junction with creek entering from the southern bank. Turbid, algal bloom and ~no macrophyte bottom cover in July-August 1997.
-	-	-	Stream area down stream to the Walla Weir construction site. This section not examined in detail. Turbid on all visits.
-	-	-	Walla Weir construction site.

RESULTS

Four species of freshwater turtles were captured in the Walla Weir area. 328 captures was recorded from all methods (Table 2) during December 1994 to August 1997. The capture rate while snorkelling was ~93% of all turtles encountered. *E. krefftii* was the most frequently encountered, accounting for 93.0% of captures. The other 3 species were rarely encountered: *Elseya* sp. 4.3% of captures; *Elseya latisternum* 0.9%; *Chelodina expansa* 1.8%. Only 2 turtles from these latter 3 species were sighted but not captured - a large and a medium sized *Elseya* sp. All turtles, representing all 4 species, whose gonads were visually examined were distinctly male or female.

Turtles were captured at all 19 study sites. However, at the junction of the 2 sites near the Bruce Highway traffic bridge, tree clearing and bank remodelling had resulted in ~100m of stream with effectively no refugia for turtles. No turtles were seen in the area on any visit. Numerous turtles were seen basking on branches and snags throughout the study area, especially during the cooler months. However, only *E. krefftii* was identified among the basking turtles.

TABLE 2. Frequency distribution by capture method for 328 freshwater turtles in the Walla Weir area. This summary treats multiple captures of the same turtle as separate events.

	Elseya sp.	*Elseya latisternum*	*Emydura krefftii*	*Chelodina expansa*
Snorkelling	14	2	206	2
Seine netting			64	
Dip netting			3	
Trapping		1	26	3
Night spotlighting			1	
Dead carcasses			3	1
Incubated eggs			2	
Total	14 (4.3%)	(0.9%)	305 (93.0%)	6 (1.8%)

EMYDURA KREFFTII

E. krefftii was the most common turtle in the river and was captured or commonly observed basking, foraging or surfacing for breaths at all sites except at the highway bridge. The turtles used fallen trees, holes under the bank supported by roots, overhanging root tangles and large stands of submerged macrophytes as refuges. Medium sized immature and adult turtles were common while few small turtles were recorded. Although the netting method was biased towards large specimens, very small turtles were not observed commonly even while snorkelling. (Turtles as small as 1yr olds are regularly captured while snorkelling in other rivers. CJL unpubl. data). Qualitative observations suggest that smaller turtles were more likely to be found in vegetated shallow, slow moving sections of the stream such as site 16. *E. krefftii* was the only species seen at night in the shallow weed-bed areas in January 1995. By day, these turtles were commonly observed swimming among logs and snags as well as walking on the bottom. Many *E. krefftii* were observed foraging in mid water among tall macrophytes during December 1994-January 1995 and in July-August 1997.

The size class distribution by sex of captured *E. krefftii* (Fig. 1) shows a low frequency of individuals among the smaller size classes. This was recognised during the study, but active searching of a range of microhabitats at different times of the year and the use of a range of capture techniques failed to locate abundant smaller size classes. Only 3 individuals (1.0%) were found with SCL~2.8-11cm. Adult males and females were the most common age class, up to maximum SCL=29.1cm and weight=3.4kg. Sex ratio was not significantly different from 1:1 among the turtles whose sex was determined.

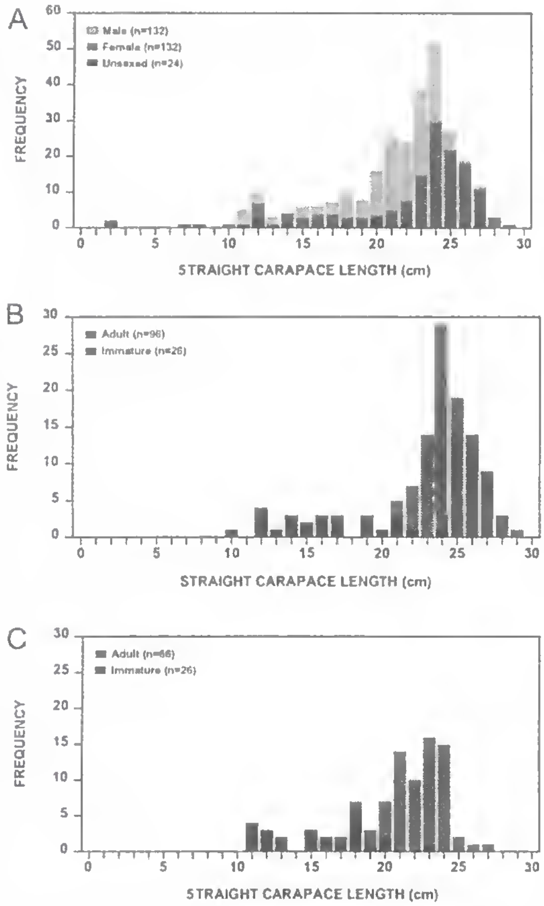

FIG. 1. Frequency distribution by size for *Emydura krefftii* from the Walla Weir area of the Burnett River.

Analysis of covariance showed significant differences between sexes for linear correlation of SCL against width (SCW); plastron length (PL) against width (PW) (Table 3; Fig. 2A,B). Head length and width were not linearly correlated (Fig. 2C). The relationship between SCL and weight was non linear (Fig. 2D). However, there was a significant linear correlation between $\log_{10}$weight and $\log_{10}$SCL for each sex and there was a significant difference between the sexes (analysis of covariance: $F_{2,268}=15.49$, $p<0.0005$):

for males, $\log_{10}(\text{weight}) = 2.9243*\log_{10}(\text{SCL}) -3.8530$ ($F_{1,140}=6574$; $r^2=0.9792$, df=140);

for females, $\log_{10}(\text{weight}) = 3.0553*\log_{10}(\text{SCL}) -4.0039$ ($F_{1,128}=4488$; $r^2=0.9723$, df=128).

These length/weight relationships provide a measure of general health of *E. krefftii*.

TABLE 3. Linear regression analysis by sex of carapace and plastron measurements of *Emydura krefftii* of all size classes from the Walla Weir area. Analysis of covariance was used to test for differences between sexes for these analyses. Regression analyses results are expressed in the form y=ax+b. * testing for coincidental regressions.

Variables		Linear regression analysis							Analysis of covariance*		
x	y	sex	a	b	F	df	p	r^2	F	df	p
SCL	SCW	male	0.576196	3.793748	1589	1,140	<0.005	0.9190	15.90	2,270	<0.0005
		female	0.618611	3.270545	1519	1,130	<0.005	0.9212			
PL	PW	male	0.417151	0.43618	838	1,138	<0.005	0.8587	10.01	2,268	<0.0005
		female	0.438256	0.341042	805	1,130	<0.005	0.8610			

Carapace length/width, plastron length/width and carapace length/weight functions have little application for field discrimination of sexes and there was no consistent difference in plastron curvature between sexes (Table 4). Most turtles had convex plastrons in longitudinal and transverse directions. The most useful external measurements for reliable identification of sex of at least some turtles were carapace length with tail length (Fig. 2E). While immature males and females may have similar tail lengths for the same SCL, most males with differentiated tails can be reliably distinguished from females. Similarly, the larger females can be distinguished reliably from males. However, Fig. 2E shows considerable overlap in the SCL/tail length distribution of immature males and of females (including immature and small adults).

Adult females were significantly larger than adult males for weight and measurements of carapace, plastron and head (Table 5). Adult males were significantly larger than adult females for all tail measurements. There is no 'knife-edge' minimum size that provided a 100% change from immaturity to adulthood for either sex. Rather, there was a wide size range over which there was a progressive change from 100% immature to 100% adult (Fig. 1B,C). This size range over which there was an increasing proportion of adults was different between the sexes. In comparing the results of logistic nonlinear and gompertz functions analyses of the proportion of adults at any size interval for each sex, it was found that the logistic nonlinear function provided the best fit to the results (Table 6, Fig. 3). Therefore, using the results of the logistic analysis, the size (± 95% confidence limits) at which 50% of the turtles were adults was:

for males, $AS_{50} = 18.89 \pm 0.081$cm;

for females, $AS_{50} = 21.07 \pm 0.015$cm.

These results provide an appropriate measure of the size at which these turtles attain sexual maturity.

During 26 December 1994 - 13 January 1995, 90% of adult female *E. krefftii* examined for breeding status (n=20) were breeding in that season: 12 had hard-shelled oviducal eggs and 1 had soft-shelled oviducal eggs. Of the remainder without oviducal eggs, 4 had mature follicles in the ovary, 1 had recently completed breeding for the season as indicated by large healing corpora lutea and atretic ovarian follicles ~4mm in diameter (13 January 1995), and 2 had not prepared for breeding in that breeding season as indicated by the largest ovarian follicles being <2mm in diameter and the absence of corpora lutea. For one of these two adult females not breeding in the 1994-1995 breeding season, the presence of corpora albicantia <1mm in diameter indicated that she had breed in a past breeding season. Some breeding females had both oviducal eggs and mature ovarian follicles ~12mm in diameter in late December indicating that they were laying multiple clutches within a breeding season. During July-August 1997, 98% of adult female *E. krefftii* examined (n=54) were in vitellogenesis with enlarging ovarian follicles in preparation for the next breeding season and none carried oviducal eggs. During 1-19 October 1996, while no turtles were examined internally to assess sex, maturity or breeding status, all short-tailed, adult sized turtles were palped for oviducal eggs. No oviducal eggs were identified in any of these turtles.

During July-August 1997, 100% of adult male *E. krefftii* examined (n=50) were breeding for the year as indicated by each having a large pendulous epididymus with a distended white duct. In contrast, of the adult males whose gonads were examined in December (n=5: x4 in 1994, x1 in 1996), only 1 had a pendulous epididymus with a distended white duct. The remaining 4 had a pendulous epididymus with a non distended duct that was translucent in appearance. These latter adult males in December are interpreted as being between periods of active spermatogenesis. As a

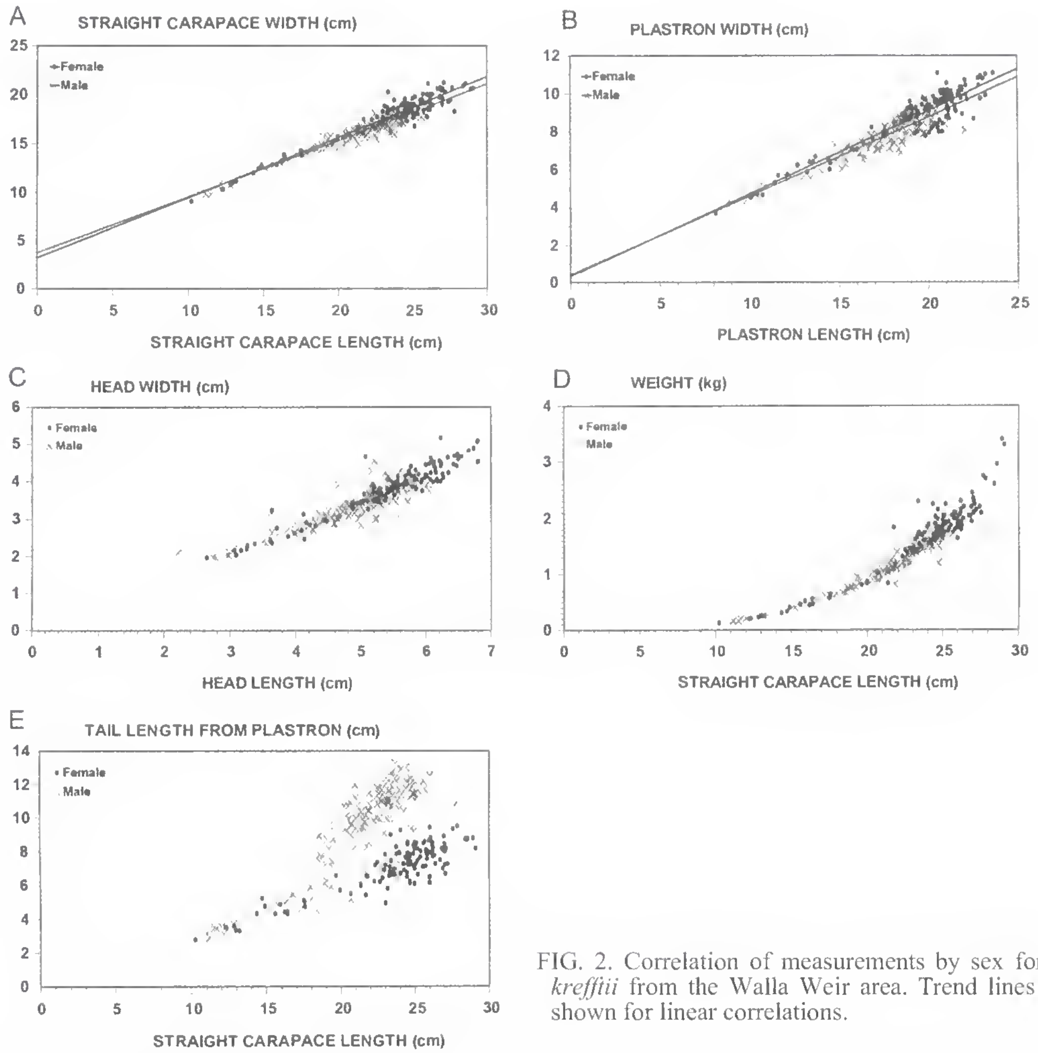

FIG. 2. Correlation of measurements by sex for *E. krefftii* from the Walla Weir area. Trend lines are shown for linear correlations.

result, the determination of the proportion of adult males breeding annually was restricted to the mid year sampling.

The breeding season has not been completely described for this population. Females with oviducal eggs were recorded during 26 December 1994 - 13 January 1995. One female laid eggs on 27 December 1994 as she was held for measurements. On 26 December 1994 there were some females with mature ovarian follicles that had yet to ovulate. While some females examined on 13 January 1995 were still in an egg production mode as judged by the presence of mature ovarian follicles that had not begun atresia, at least one female had completed its breeding season by that date (see above). These females lay eggs during a mid summer breeding season without synchronised periods of ovulation and apparently without necessarily synchronised oviposition for the population. Some females are laying multiple clutches within a breeding season. The number of clutches per season and the number of eggs per clutch were not determined.

For the partial clutch of 5 eggs laid on 27 December 1994 (female tag number 13349; SCL = 25.75cm; Weight = 2.1kg): mean egg length = 3.58cm (SD = 0.153, range = 3.38-3.78); mean egg width = 2.13cm (SD = 0.153, range = 2.05-2.19); mean egg weight = 9.2g (SD = 0.261, range = 8.8-9.6). Two eggs hatched after an incubation period of 63 and 64 days, respectively. Mean hatchling measurements are summarised as follows:

TABLE 4. Frequency distribution of plastron curvature by sex and maturity for *E. krefftii* in the Walla Weir area. L denotes curvature along the length of the plastron. W denotes plastron curvature across the width of the plastron over the mid point.

Sex	Maturity	Plastron curvature								
		Convex L			Flat L			Concave L		
		Convex W	Flat W	Concave W	Convex W	Flat W	Concave W	Convex W	Flat W	Concave W
female	adult	81	2	0	0	0	0	1	0	0
female	immature	16	1	0	0	1	0	4	0	1
male	adult	68	0	0	4	2	0	9	0	4
male	immature	18	2	0	0	0	0	4	0	0

SCL=2.75cm (range=2.46-2.95); SCW=2.485cm (range=2.27-2.70); PL=2.315cm (range=2.13-2.50); PW=1.215cm (range=1.11-1.32); HL=1.11cm (range=1.10-1.12); HW=0.975cm (range=0.92-1.03); TLC=+0.61cm (range=0.58-0.64); TLP=0.78cm (range=0.71-0.85); TLV=0.485cm (range=0.44-0.53); WT=5.1g (n=1).

There were 6 short term recaptures of *E. krefftii* (1-23d; 2 adult female, 2 immature female, 1 adult male, 1 immature male) and all recaptures occurred within the original capture site. There were 5 long term recaptures from 4 *E. krefftii* (0.78-2.64yr; all adult females). Of these, 2 were recaptured in the same site (=displacements of no greater than a few hundred metres) and the remaining 3 recaptures involved movements exceeding 1km. Female 13364 moved ~1km upstream between 1 Jan 1995 - 23 Aug 1997. Female 13406 moved ~1km upstream between 1 Jan 1995 and 16 Oct 1996 and was recaptured ~0.5km downstream from the original capture site on 29 July 1997. The low proportion of recaptured turtles indicates either a very large population in the Walla Weir area or considerable movement of turtles within the river. Recorded displacements suggest home ranges greater than 1km of river. Considerably more recaptures are needed to resolve questions concerning site fidelity and home range.

While most turtles were characterised by the standard scute count of 1 nuchal, 5 vertebrals, 4/4 costals and 12/12 marginals, 11.2% of *E. krefftii* had a non standard count (Table 7).

ELSEYA SP.

Elseya sp. was not abundant in any part of the river with 16 sightings for 14 captures of 13 turtles. It was recorded in only four small sections of the surveyed area. Eight captures were within <100m of one pool, immediately adjacent to the structural remains of the water uptake site for the old Wallaville Sugar Mill (study site 11). Almost all sightings (14/16) occurred from this site downstream for ~1km along this steep sided bend of the river (sites 11, 13 and 14). The remaining 2 sightings (including 1 capture) were at site 8. All capture sites were in 2-6m deep sections of the river with a steeply inclined underwater bank. All capture sites except site 8 were associated with large submerged rocks and snags. All were foraging or resting at the bottom of the stream when first encountered and there were no aquatic macrophytes growing at these locations.

TABLE 5. Measurements of *Emydura krefftii* from the Walla Weir area.

Measurement	Adult female				Adult male			
	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	25.10	1.557	21.73-29.10	96	22.90	1.717	18-56-27.83	66
Straight carapace width (cm)	18.82	1.068	16.20-21.24	96	16.97	1.074	14.48-19.14	66
Plastron length (cm)	20.63	1.244	18.06-23.69	96	18.45	1.276	14.78-21.84	65
Plastron width (cm)	9.46	0.742	7.91-11.09	96	8.41	0.694	6.56-10.05	64
Head length (cm)	5.76	0.464	4.85-6.80	96	5.14	0.436	4.05-6.05	64
Head width (cm)	4.05	0.405	3.27-5.16	96	3.55	0.382	2.79-4.55	64
Tail length from carapace (cm)	3.45	0.868	0.80-5.41	90	6.84	1.430	3.83-11.45	60
Tail length from plastron (cm)	7.61	0895	4.96-9.51	90	10.79	1.276	7.85-13.25	60
Tail length from Vent (cm)	4.08	0.746	1.63-5.75	89	4.85	0.822	3.59-8.11	60
Weight (kg)	1.917	0.373	1.192-3.400	96	1.333	0.271	0.674-1.822	66

TABLE 6. Estimate of size at first breeding for *E. krefftii*: results of analysis of the ratio of adult to immature per 1cm size increments by sex for the data summarised in Fig. 3. A, Logistic function_analysis; equation: proportion mature = 1/ (1+EXP(-b*(scl-c))). B, Gompertz function analysis; equation: proportion mature = EXP(-EXP(-b*(scl-c))).

A	Male			Female		
	value	Standard error	T-ratio	value	Standard error	t-ratio
Coefficient b	1.5535	0.28924	5.3710	2.5918	0.38949	6.6544
Coefficient c	18.885	0.040418	467.23	21.073	0.0076874	2741.2
Residual sum	-0.15122			-0.20340		
Residual variance	0.0049432			0.0013822		
Log-likelihood function	11.12341			14.98493		
df	7			6		
B		Male			Female	
	value	Standard error	T-ratio	value	Standard error	t-ratio
Coefficient b	9.8502	0.99828	9.8671	8.2830	1.1757	7.0449
Coefficient c	19.889	0.096949	205.15	20.989	2.0089	10.448
Residual sum	0.74704			-0.17702		
Residual variance	0.052084			0.0026914		
Log-likelihood function	0.5265644			12.31928		
df	7			6		

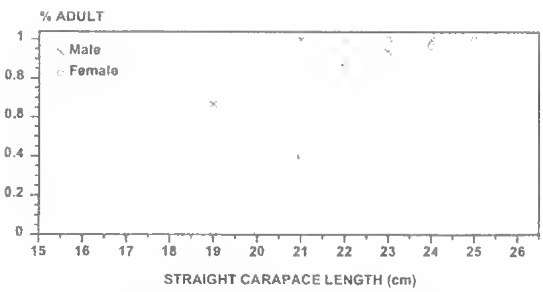

FIG. 3. Calculation of AS_{50} values for female and male *E. krefftii* from the Walla Weir area.

Laparoscopic examination of the cloaca showed two large sac-like structures (=cloacal bursae) leading anteriorly from the cloaca to lie within the posterior body cavity. During laparoscopic examination of the gonads, these bursae were visible in the body cavity and were positioned one either side of the bladder. The posterior portion of each bursa was crowded with numerous thin-walled, branched but flattened processes, each well supplied with blood vessels. Muscular action of the bursae flushed water, via the vent, in and out of the sacs and past the vascularised processes. In contrast, *E. krefftii* observed in a similar manner had much smaller cloacal bursae with only relatively small areas of branched processes. The large cloacal bursae and associated vascularised processes of *Elseya* sp. resemble the cloacal gill systems of *Rheodytes leukops* (Legler & Cann, 1980) and *E. georgesi* (= *E. latisternum* of King & Heatwole, 1994a).

The 13 *Elseya* sp. ranged from small immature turtles with SCL=11.48cm to large adults with SCL=38.8cm. The sample contained 6 females (4 adult, 2 immature), 4 males (2 adult, 2 immature) and 3 unsexed immature turtles. The size class distribution by sex of captured *Elseya* sp. is summarised in Fig. 4. A summary of the size by weight distribution is shown in Fig. 5. The size and weights of adult male and female *Elseya* sp. from the Walla Weir area are summarised in Table 8. Within this small sample, the adult females were much larger than the adult males except that adult males had longer tails than females. It was not possible to quantify AS_{50} values from this sample.

The small sample limits definition of the breeding season in this part of the Burnett R. The 3 adult females captured in July 1997 were in early vitellogenesis in preparation for the next breeding season and each also had healing corpora lutea on their ovaries resulting from a breeding season earlier in the year. The 2 adult females captured in early January 1995 were in advanced vitellogenesis for an approaching nesting season and neither had corpora lutea on the ovaries. None from either sample contained oviducal eggs. These observations are consistent with oviposition occurring during approximately

TABLE 7. Frequency distribution of scute counts for chelid turtles from the Walla Weir area. For paired scutes, the left side was counted first.

Scute	Scute count	Frequency			
		Emydura krefftii	*Elseya* sp.	*Elseya latisternum*	*Chelodina expansa*
nuchal	0	10	12	2	4
	1	276	1	0	0
vertebral	5	285	12	2	0
	6	1	0	0	2
	7	0	1	0	2
costals	3/3	0	0	0	1
	4/3	1	0	0	0
	4/4	275	11	2	2
	4/5	1	1	0	0
	5/4	8	0	0	0
	5/5	1	0	0	0
	5/6	0	1	0	1
marginals	11/10	1	0	0	0
	11/12	1	0	1	0
	11/13	2	0	0	0
	12/11	2	0	0	1
	12/12	271	13	1	3
	12/13	3	0	0	0
	13/12	4	0	0	0
	13/13	2	0	0	0

autumn or early winter. For the 5 captures of 4 adult females, all were in vitellogenesis. This indicates that the annual breeding rate of adult females may approach 100%. Both adult males captured in late July 1997 were in active sperm production for the next breeding season as indicated by an enlarged white duct within the pendulous epididymus.

The 5 immature *Elseya* sp. captured in December 1994-January 1995 each had 5 growth layers not including the hatchling layer on several scutes. These indicated that they were part of a single year cohort born in 1990. The immature specimen captured in July 1997 had 6 growth layers not including the hatchling layer on several scutes indicating birth in 1991.

The single recapture was of an adult female, tag 13408, originally tagged on 1 Jan 1995 (SCL=37.9cm, 6.85kg). She was recaptured within 10m of her original capture site on 29 Jul 1997 (2.58yr at large and two wet seasons of floods between captures). She had grown 0.9cm in SCL (growth rate = 0.34cm/yr) and lost 0.35kg in weight between captures.

While most turtles were characterised by the standard scute count of 0 nuchal, 5 vertebrals, 4/4 costals and 12/12 marginals, 23% of *Elseya* sp. had a non standard count (Table 6).

ELSEYA LATISTERNUM

Only 2 specimens were recorded (immature male, SCL=16.12cm, weight=0.468kg; adult female, SCL=22.46cm, weight=1.57cm). Both were captured in larger pools 2-6m deep. The adult female (13869) was classed as an adult that had yet to breed. It had no corpora albicantia and no corpora lutea in the ovaries, but small vitellogenic follicles and atretic disks ~2mm in diameter resulting from past atresia of enlarged vitellogenic follicles. This female had entered a past vitellogenic cycle, but had not ovulated. This is not necessarily indicative of an environmental problem as failure to breed on the first vitellogenic cycle has been recorded as normal for young adult females of other chelid species (Kuchling & Bradshaw, 1993) and marine turtles (Limpus, 1990). The immature male was recaptured within the same site 4d after its original capture. Scute counts for *E. latisternum* are summarised in Table 7.

E. latisternum is usually more abundant in the upper reaches of streams in more elevated areas (CJL, unpublished data) and the Walla Weir area of the Burnett R. is considered marginal to its normal distribution in this river.

CHELODINA EXPANSA

During the entire study, only 5 specimens were captured in the river and another was recovered as a carcass on the bank. They ranged from immature turtles (SCL=15.74cm) to adults (SCL =29.05cm). For scute counts see Table 7.

DISCUSSION

This baseline study of freshwater turtles in the Walla Weir area of the Burnett R. has shown *Elseya* sp. to be an uncommon species for the

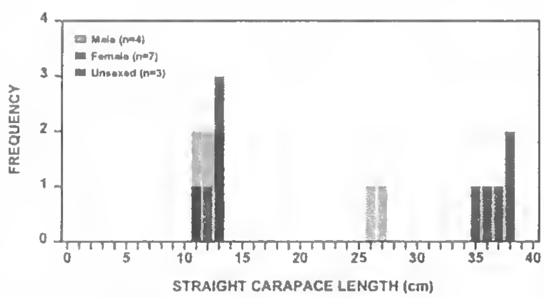

FIG. 4. Frequency distribution by size and sex for *Elseya* sp. from the Walla Weir area.

TABLE 8. Measurements of adult *Elseya* sp. from the Walla Weir area.

Measurement	Adult female				Adult male			
	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	37.42	1.16	35.6-38.8	5	27.27	0.33	26.94-27.6	2
Straight carapace width (cm)	29.83	0.61	28.95-30.65	5	21.86	0.04	21.82-21.90	2
Plastron length (cm)	30.92	0.46	30.53-31.82	5	21.89	0.05	21.84-21.94	2
Plastron width (cm)	14.41	0.79	13.51-15.76	5	10.10	0.21	9.89-10.31	2
Head length (cm)	9.65	0.64	8.52-10.33	5	7.19	0.25	6.94-7.44	2
Head width (cm)	6.87	0.28	6.66-7.40	5	4.98	0.19	4.79-5.16	2
Tail length from carapace (cm)	3.01	0.77	2.02-4.39	5	8.00	0.53	7.47-8.52	2
Tail length from plastron (cm)	10.13	0.82	9.44-11.73	5	14.64	0.06	14.58-14.69	2
Tail length from vent (cm)	6.97	0.77	6.08-8.34	5	7.32	0.14	7.18-7.45	2
Weight (kg)	6.62	0.19	6.35-6.85	5	2.17	0.03	2.15-2.20	2

area. A small area adjacent to the site of the old Wallaville Sugar Mill has been identified where the majority of specimens were concentrated. The population in 1994-1997 consisted of a few large adults and a small cohort(s) of immature turtles born in about 1990-91. This population structure suggests that the species was not functioning well during the study period. The reasons for this current population structure could not be assessed within the short time frame of this baseline study developed since the presentation of the Boardman (1996) review and required to be completed before water levels rose with the construction of the Walla Weir in late 1997. The identification of a cloacal gill system in *Elseya* sp. resembling the cloacal gills of species with aquatic respiration such as *Elseya georgesi* (King & Heatwole, 1994a,b) and *Rheodytes leukops* (Priest, 1997) indicated that the diving physiology of *Elseya* sp. warranted investigation. Such a study has commenced and *Elseya* sp. from the Mary R. has been found to have a very well-developed capacity for aquatic ventilation (FitzGibbon, 1998). However, the impact of impoundment with lowered dissolved oxygen concentrations on life history parameters for this species remains unresolved.

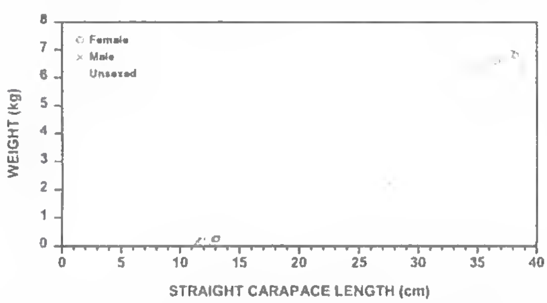

FIG. 5. Distribution of the size by weight of *Elseya* sp. from the Walla Weir area.

An adequate set of statistically described parameters suitable for assessment of temporal changes in the dynamics of a freshwater turtle population requires a sample of some hundreds of individuals of the species being examined. It is now apparent that it was not logistically possible to capture a sample of hundreds of *Elseya* sp. from the Walla Weir area of the Burnett R. within a short period. Any assessment of temporal change for *Elseya* sp. within the Walla Weir following elevation of water level within the impoundment must be made in comparison with the performance of the much more abundant species *E. krefftii* within the Walla Weir and with *Elseya* sp. populations elsewhere.

Examination of the large sample of *E. krefftii* during the baseline study has provided data that, on comparison with a comparable data set following elevation of water levels in the impoundment, should enable temporal changes in population function to be assessed within the area. These parameters include size class distribution by sex, size class distribution by maturity for each sex, estimation of the size for first breeding (AS_{50}) for each sex, mean size of breeding adults for each sex, annual breeding rate for adults of each sex and length/weight condition curves for each sex. These types of parameters can be measured during short term studies independent of long term mark-recapture studies.

Accurate recording of data that includes sex, maturity and breeding status of freshwater turtles usually requires the examination of the gonads and associated ducts. The present study has demonstrated that external measurements do not provide knife-edge delineation of either sex or maturity and they provide no clear indication of breeding condition. Breeding adult females can be identified by palpation of soft-shelled and hard-shelled oviducal eggs. Conservation ethics preclude the killing of large series of turtles to obtain reproductive data. Therefore, assessing sex, maturity and breeding status of live turtles requires alternative methods. In this context, radiography is limited to identifying the presence of and counts of shelled oviducal eggs and hence identifying gravid females (Kuchling, 1998). However, when considering health hazards, Kuchling (1998) has urged caution in using radiography for routine screening of turtle populations to obtain reproductive data. In contrast, the benign technique of ultrasound scanning can provide detailed images for most stages of the female reproductive cycle including vitellogenic and atretic follicles in the ovaries and freshly ovulated ova, and soft-shelled and hard-shelled oviducal eggs in the oviducts (Kuchling, 1998). Unfortunately, ultrasound scanning does not provide resolution of soft bodied organs such as oviduct, testis and epididymus (CJL unpublished data). Ultrasound scanning is, therefore, limited in application for determining the sex of small turtles, for determining the change from immature to mature in males and early adult females, and for determining presence or absence of spermatogenesis of adult males. Examination via laparoscopy provides for direct visual inspection of the gonads and associated ducts with a high degree of visual resolution and has been used extensively in population dynamics studies of marine turtles (Limpus & Reed, 1985; Limpus, 1992; Limpus et al., 1994a,b), terrestrial turtles (Robeck et al., 1990; Rostal et al., 1994) tuatara (Cree et al., 1991) and crocodiles (Limpus, 1984). Use of laparoscopic examination in the present study demonstrates the wide range of reproductive parameters that can be obtained from a sample that includes a wide cross-section of sizes of a population. As with any surgical procedure there may be a health risk to the 'patients', but this risk can be minimised to <0.2% mortality through adequate surgical training in the use of the equipment, in depth knowledge of turtle anatomy and use of field surgical procedures that approach sterile conditions.

With long-lived species such as freshwater turtles (Parmenter, 1985; Gibbons, 1989; Kennett, 1994), adult turtles can be plentiful in a population for a very long time, even if hatchling recruitment is severely compromised (Thomson, 1983; Congdon et al., 1993). A significant limitation on clarifying population dynamics for Australian freshwater turtle populations is the current lack of a reliable technique for determining the age of live turtles. Addition of age to the suite of variables measured would significantly improve the capacity to identify change in population dynamics. If changes are detected within a turtle population at a site like the Walla Weir, it is unlikely that the underlying causes of change can be identified in the absence of comprehensive long term studies. Comprehensive demographic and ecological data is available for only one species of Australian freshwater turtle — the endangered *P. umbrina* from southwestern Australia (Kuchling & Bradshaw, 1993; Kuchling et al., 1992).Similar data for Queensland freshwater turtle species would benefit management planning for conservation.

The paucity of small immature turtles in the *E. krefftii* population and the limited size class representation in the *Elseya* sp. population at Walla Weir is reminiscent of the stressed populations of *E. macquarii* and *C. longicollis* in the Murray R. where predation of eggs was identified as a significant problem limiting hatchling recruitment (Thomson, 1983). This latter study indicates the need to address more than in-river problems with freshwater turtle conservation issues.

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